

Morphologic Changes of the Posterior Cruciate Ligament on Magnetic Resonance Imaging before and after Reconstruction of Chronic Anterior Cruciate Ligament Ruptures

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Purpose: The purpose of this study was to compare the morphologic change of the posterior cruciate ligament (PCL) on magnetic resonance imaging (MRI) in chronic anterior cruciate ligament (ACL) tear before and after reconstruction.

Materials and Methods: On the MRI image after ACL reconstruction, a base line (BL) was drawn between the femoral and tibial insertion sites of the PCL. Point A was established as the vertically farthest point from BL. Line 1 and 2 were drawn respectively between point A and the insertions of PCL. The angles between BL and Line1 and 2 were defined as angle a and angle b. Correlations between the preoperative anterior knee instability assessed with the KT 1000 arthrometer and the parameters were evaluated.

Results: The average angle a was $52.3^\circ \pm 7.1^\circ$ preoperatively and $30.1^\circ \pm 3.4^\circ$ postoperatively, and the average angle b was $28.95^\circ \pm 4.62^\circ$ preoperatively and $22^\circ \pm 2.9^\circ$ postoperatively ($p < 0.05$). The preoperative manual maximal side-to-side difference was 7.2 ± 2.3 mm, which had no significant correlation with angle b.

Conclusions: The preoperative buckling of PCL in the case of chronic ACL injury disappeared after ACL reconstruction. The degree of PCL buckling had no correlation with the degree of preoperative anterior instability.

Key words: Knee, Magnetic resonance imaging, Anterior cruciate ligament, Posterior cruciate ligament, Buckling.

Introduction

Magnetic resonance imaging (MRI) is a highly effective diagnostic modality for the detection of anterior cruciate ligament (ACL) tears. However, in cases of chronic ACL deficiency, MRI findings can be misleading, if ACL remnants are attached to the

posterior cruciate ligament (PCL) or some fibrous tissues are well preserved. In such cases, PCL buckling, a secondary sign of chronic ACL tear can be a valuable clue to diagnosis¹⁾.

Typical MRI findings of ACL tear include partial or complete discontinuity of the ligament and abnormal morphology on T1-weighted image^{2,3)}. PCL buckling can be observed in cases of acute or chronic ACL tears. Some studies associated sigmoid or curved appearance of the PCL more with chronic than acute ACL tears⁴⁾.

Our hypothesis was that PCL buckling would disappear after ACL reconstruction if it was associated with anterior tibial translation that results from ACL injury. In this study, we evaluated the pre- and postoperative morphological changes of the PCL on MRI scans in patients with chronic ACL injury.

Materials and Methods

1. Patients

Of the patients who underwent ACL reconstruction between March 2006 and March 2010 at our institution, 38 patients

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who were available for MRI evaluation within 3 months after surgery were included in this study. There were 34 males and 4 females with a mean age of 32 years (range, 20 to 45 years). The indications for surgery were medial collateral ligament injury in 6, medial meniscal tear in 14, and lateral meniscal tear in 6 patients. The causes of injury were football in 15, basketball in 3, foot volleyball in 2, falling while hiking in 3, and unidentified in 15 patients. ACL reconstruction was performed using a hamstring tendon autograft in 19 and a double-bundle semitendinosus tendon autograft in the remaining 19 patients. Anterior knee instability was measured with the KT-1000 arthrometer pre- and postoperatively.

2. Measurements

T1- and T2-, and proton-density-weighted sagittal, coronal, and axial images with a slice thickness of 5 mm were obtained using a 1.5 Tesla scanner (Magnetom Vision-VB33A, Siemens, Malvern, PA, USA). MRI was performed with the patient in the supine position and the knee at 20° flexion and at 15° external rotation in a surface coil. The degree of PCL buckling on the obtained images was assessed using the method of Choi et al.¹⁾

On the pre- and postoperative sagittal plane MRI images that optimally demonstrated the whole PCL, a base line (BL) that connects the centers of insertion sites of the PCL in the femur and tibia was drawn. Point A was established at a vertically farthest point from BL, from which line 1 that was extended

to the femoral attachment and line 2 to the tibial attachment were drawn. The angle between BL and line 1 was defined as angle a and the angle between BL and line 2 as angle b. A line perpendicular to BL from point A was drawn and the point of intersection was determined as point B. The distance between point A and point B was defined as D. The ratio between the distance from the tibial attachment of the PCL to point B and BL was calculated (ratio a) (Fig. 1). We analyzed the pre- and postoperative differences in D, ratio a, angle a, and angle b that were measured on MRI images. The relationship between the preoperative manual maximal side-to-side difference (MMSD) measured using the KT-1000 arthrometer and the abovementioned parameters were assessed. Measurements were performed by two orthopedic surgeons three times each and the average values were used for analysis.

3. Statistical Analysis

The data was analyzed using the SPSS ver. 18 (IBM, Armonk, NY, USA). A paired t-test was conducted to evaluate the D, ratio a, angle a, and angle b with a significance level set at $p < 0.05$. The relationship between the preoperative KT-1000 measurements and the angle b was evaluated by Pearson correlation analysis with a significance level set at $p < 0.05$.

Results

The average angle a was $52.3^\circ \pm 7.1^\circ$ (range, 39° - 71°) preoperatively and $30.1^\circ \pm 3.4^\circ$ (range, 24° - 39°) postoperatively. The average angle b was $28.9^\circ \pm 4.6^\circ$ (range, 20° - 37°) preoperatively and $22^\circ \pm 2.9^\circ$ (range, 15.9° - 26°) postoperatively ($p < 0.05$). The average D was 6.38 ± 1.7 mm (range, 3.4-9.9 mm) preoperatively and 3.77 ± 1.3 mm (range, 1.8-6.8 mm) postoperatively ($p < 0.05$) (Fig. 2). The average ratio a was $67.2\% \pm 5.8\%$ (range, 55.5-79%) preoperatively and $55.2\% \pm 7.6\%$ (range, 43.2-66.4%) postoperatively ($p < 0.05$). The average preoperative MMSD was 7.20 ± 2.3 mm (range, 6-13 mm), which was not correlated with angle b (Pearson's correlation coefficient=0.245, $p < 0.05$).

Discussion

Primary MRI findings of ACL injury include discontinuity of the ligament on T1- or T2-weighted images, an intermediate-signal-intensity mass near the ACL on T1-weighted image, posterior bowing of the ACL, poor visualization or nonvisualization of the ACL on T1-weighted image in the presence of PCL buckling^{1,2,4-7)}. Secondary signs include bone

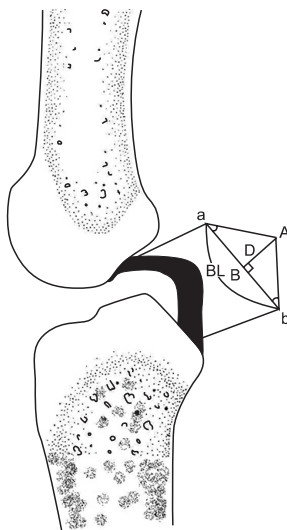


Fig. 1. The schematic diagram of posterior cruciate ligament (PCL) on magnetic resonance imaging. Angle a: angle between base line (BL) and line 1, Angle b: angle between BL and line 2, BL: line between the femoral attachment and tibial attachment of the PCL, D: the distance between points A and B.



Fig. 2. After anterior cruciate ligament (ACL) reconstruction, the buckling of posterior cruciate ligament decreased. (A) Preoperative image. (B) Image after ACL reconstruction.

contusion or fracture of the posterior aspect of the lateral tibial condyle or middle of the lateral femoral condyle^{2,6,8)}, anterior translation of the lateral tibial condyle, posterior translation of the posterior horn of the lateral meniscus, deepening of the lateral femoral condylar notch⁵⁾, and diffuse thickening of the ACL, and protrusion or irregularity in the medial border on T1-weighted transverse images¹⁾.

Anterior subluxation of the tibia is a sign of full-thickness ACL tears. In the absence of ≥ 5 mm subluxation, MRI has a sensitivity of 86% and a specificity of 99% for the detection of full-thickness ACL tears^{9,10)}. Anterior subluxation of the tibia relative to the femur induces changes in the appearance of the PCL to a sigmoid shape or hyperbuckling^{8,9)}. Such morphological changes of the PCL have been well documented in the study by Choi et al.¹⁾ and we also observed increases in the angle α in our patients. Choi et al.¹⁾ suggested that angle α was a significant predictor of the diagnosis of chronic ACL tears. However, we found there was little correlation between the angle α and the anterior instability, and thus believe that PCL buckling on MRI images is not correlated with anterior instability. In our understanding, anterior subluxation of the tibia may also be influenced by injuries to the medial meniscus, PCL tears, which we could not identify with an MRI, and abnormality of the secondary stabilizers of the knee. In the study by Choi et al.¹⁾, angle α was $56.1^\circ \pm 41.4^\circ$ in the ACL tear group and $39.7^\circ \pm 10.0^\circ$ in the normal group. In our study, angle α in patients with ACL tears decreased from $52.3^\circ \pm 7.1^\circ$ preoperatively to $30.1^\circ \pm 3.4^\circ$ postoperatively. Although we could not confirm normalization of the PCL shape, because side-to-side assessments were not doable postoperatively, the degree of PCL buckling decreased after ACL reconstruction. Rak et al.⁷⁾ reported that PCL buckling after ACL reconstruction was suggestive of ACL graft laxity. Horton et al.¹⁰⁾ reported that PCL

buckling was present in 37.5% of full-thickness ACL graft tears, in 43% of partial tears, and in 30% of intact grafts. Their study showed that PCL buckling had 41% sensitivity, 70% specificity, 76% positive predictive value, and 35% negative predictive value for the diagnosis of full-thickness or partial-thickness tears of the ACL reconstruction grafts^{9,10)}.

The clinical implication of this study is that we could confirm that PCL buckling is caused by anterior subluxation of the tibia in ACL tears, considering that hyperbuckling disappears after ACL reconstruction. Therefore, we think a PCL buckling that is present after ACL reconstruction is suggestive of ACL laxity.

Conclusions

PCL buckling that results from anterior translation of the tibia in chronic ACL injury disappeared after ACL reconstruction. There was no correlation between the degree of PCL buckling and anterior instability.

References

1. Choi NH, Kim MK, Yoon YJ, Yoo JD, Lee HM. Morphological change of PCL of MRI in the tear of ACL. *J Korean Orthop Assoc.* 1996;31:371-6.
2. Mink JH, Reicher MA, Crues JV, Deutsch AL. *MRI of the knee.* 2nd ed. New York: Raven Press; 1993. p141-62.
3. Vahey TN, Broome DR, Kayes KJ, Shelbourne KD. Acute and chronic tears of the anterior cruciate ligament: differential features at MR imaging. *Radiology.* 1991;181:251-3.
4. Ahn JM, Kang HS, Kim SM, Seong SC. Injury of the ligaments of the knee: magnetic resonance evaluation. *J*

- Korean Radiol Soc. 1992;28:269-74.
5. Lee YJ, Kim YS, Lee JH, Park JO, Woo JH, Ki TS, Chung JW, Lee DY. The role and importance of T1 weighted axial image on the diagnosis of anterior cruciate ligament tear. J Korean Radiol Soc. 1994;31:949-54.
6. Stallenberg B, Gevenois PA, Sintzoff SA Jr, Matos C, Andrianne Y, Struyven J. Fracture of the posterior aspect of the lateral tibial plateau: radiographic sign of anterior cruciate ligament tear. Radiology. 1993;187:821-5.
7. Rak KM, Gillogly SD, Schaefer RA, Yakes WF, Liljedahl RR. Anterior cruciate ligament reconstruction: evaluation with MR imaging. Radiology. 1991;178:553-6.
8. Boeree NR, Ackroyd CE. Magnetic resonance imaging of anterior cruciate ligament rupture. A new diagnostic sign. J Bone Joint Surg Br. 1992;74:614-6.
9. Edelman RR, Hesselink JR. Clinical magnetic resonance imaging. 1st ed. Philadelphia: WB Saunders Co; 1990. p996.
10. Horton LK, Jacobson JA, Lin J, Hayes CW. MR imaging of anterior cruciate ligament reconstruction graft. AJR Am J Roentgenol. 2000;175:1091-7.